AN OUTLINE OF THE PHYSIOGRAPHIC HISTORY OF NORTHEASTERN ONTARIO[1]

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The region here referred to as northeastern Ontario is one about 250 miles square, lying between Lake Superior and the Quebec boundary and reaching from Lake Huron north to the Transcontinental Railway. Its topography has been described so many times in reports of the Geological Survey and of the Ontario Bureau of Mines that no extended account of it is needed in this place. The region is referred to by geologists and topographers as a glaciated peneplain. As a matter of fact it is a hilly country and only conveys an impression of flatness when a large area is seen at one time. Viewed from the top of one of the more commanding hills the horizon appears as an even line and the intervening hills can be seen to stand at about the same elevation. The rivers have slopes of only 5 to 10 feet a mile, and the highest and lowest points on the railways which cross the region are 1,350 and 600 feet above sea.

This condition holds true for most of northeastern Ontario. There are a few places, however, where the relief is greater, and where significant traces remain of a former topography of more rugged character. There is, for example, one hilltop, about 40 miles west of Sudbury, from which one can see, on a fine day, a line of white hills on the southern horizon that certainly remind one of mountains. These are the Lacloche Mountains, to which further reference will be made. It also requires considerable scientific faith to acknowledge the wild country bordering Lake Superior as plainlike or nearly plainlike.

In the case of a true plain, like the Mississippi basin, or the western plains of Canada, the impression of tranquillity conveyed by the landscape is borne out by the rocky structure underneath.

[1] Read before Section E, American Association for the Advancement of Science, December 27, 1921.

The rock formations are all sediments, deposited by the subdued agencies of water or of wind. They lie in horizontal beds, free from stress.

The mild topographic aspect of most of northern Ontario might lead one to expect somewhat the same undisturbed condition underground. This is not found, however. It is not asserted here that some of the rock formations are not flat-lying or nearly so. Some of them are; but the prevailing condition is quite different. Characteristically, the stratified formations of northern Ontario are folded, twisted, sheared, and broken in the most extraordinary manner. They spring from deep underground in arches that are abruptly truncated by the surface of the peneplain. In places they have been broken by faults so great that the two sundered parts of a formation, that once lay face to face, are now found from a few hundred feet to a mile apart. They are cut by dikes and sills of rocks that were once molten, and a large share of the present surface of the region is now underlain by batholithic masses of granite, once molten, a hundred miles or so in diameter, and of unknown depth. The condition is one of suspended geological turmoil of incredible magnitude and violence.

There is something dramatic and stirring to the imagination in this contrast between the mild landscape of the present northern Ontario and the evidence of telluric convulsion that lies just beneath it; a contrast which impels one to speculate about the cause of this violence, in what manner it expressed itself at the surface of the earth, and what have been the processes of change between then and now.

The characteristic geological features of this region, as contrasted with those of a true plain, are the extreme deformation of the stratified formations, and the presence of igneous formations, particularly the batholiths of granitic rocks. If one studies a geological map of North America (Fig. 1), it is soon apparent that, outside of the great Precambrian Shield region, to which northern Ontario belongs, the greatly folded and faulted rocks are confined to the mountain regions—the Western Cordillera and the Appalachian Mountains along the Atlantic Coast. It can be seen at the same time that great granite masses, the batholiths, are present

in these mountain regions, and nowhere else in the continent, except, of course, in the Precambrian Shield.

This conjunction of batholithic intrusions with mountain systems is no new observation. It has been long noted and there

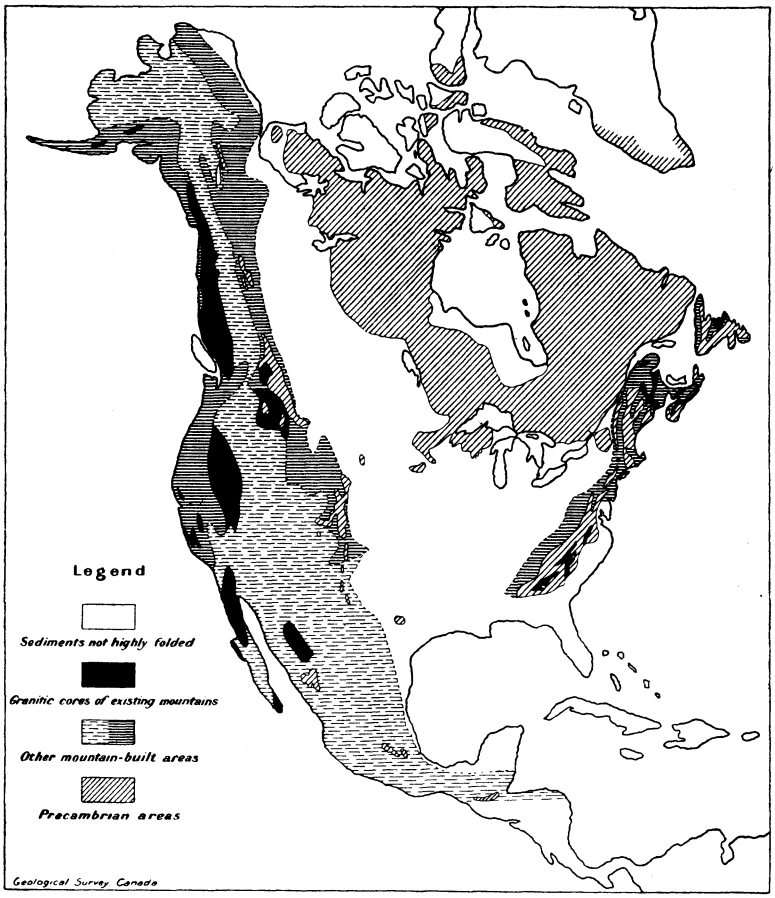

FIG. 1.—Map of North America to show the distribution of batholithic intrusions in relation to mountain-building.

has been much speculation as to the nature of the association—whether the compression and upheaval of the earth's crust caused the igneous invasions or whether the latter were causes or mere concomitants of mountain-building. Nor has the analogy between

the deformed strata and intrusive batholiths in mountain regions and in the flat, Precambrian Shield, been overlooked; but the apparent total absence of actual mountains in the Precambrian Shield, as well as its enormous area, exceeding that of any known mountain system, have led geologists to accept the theory of Precambrian mountain-building with reservations, or even to prefer the explanation that the Precambrian Shield is part of the original crust of a once molten world.

Let us compare the mountains of North America in respect to their ages, their topographic aspects and the abundance in them of batholithic rocks. The accompanying illustration (Fig. 2), compiled by J. F. Wright, of the Geological Survey, Ottawa, shows a series of representative cross-sections through the Rocky Mountains, the Coast Mountains, the Appalachians, the stumps of the ancient Acadian Mountains of Nova Scotia, and through a part of the peneplain of northeastern Ontario. The sections are arranged in order of age from youngest to oldest, are all referred to sea-level and drawn to the same horizontal and vertical scales, the relief being exaggerated twenty-one times.

The Rocky Mountains, which date from early Tertiary time, reach elevations of 10,000 to 12,000 feet, have an extremely sharp profile and reveal no batholithic intrusions, although some distance south of the line of section the Ice River syenite mass does reach the surface. The Coast mountains, of Jurassic age, reach about 7,000 feet above sea, and more than one-third of the section is of batholithic granitic rocks. These mountains are scarcely less sharp in profile than the Rockies; but that is due to the fact that they have been elevated twice and are now being carved a second time. The Appalachians were formed about Permian time, and have suffered erosion for a correspondingly longer time than the Coast and Rocky mountains. They reach only 2,800 feet above sea, have a comparatively gentle skyline, and erosion has laid bare a larger proportion of their granite core. The Acadian Mountains can be called such only in a genetic sense. They possess a relief of only a few hundred feet, and their granite core is freely exposed. They are the barely recognizable roots of mountains, and not more deserving of the designation than those shown in the next and last section.

Reference was made in the first paragraphs of this paper to Lacloche Mountains, south of Sudbury, as one of the topographic

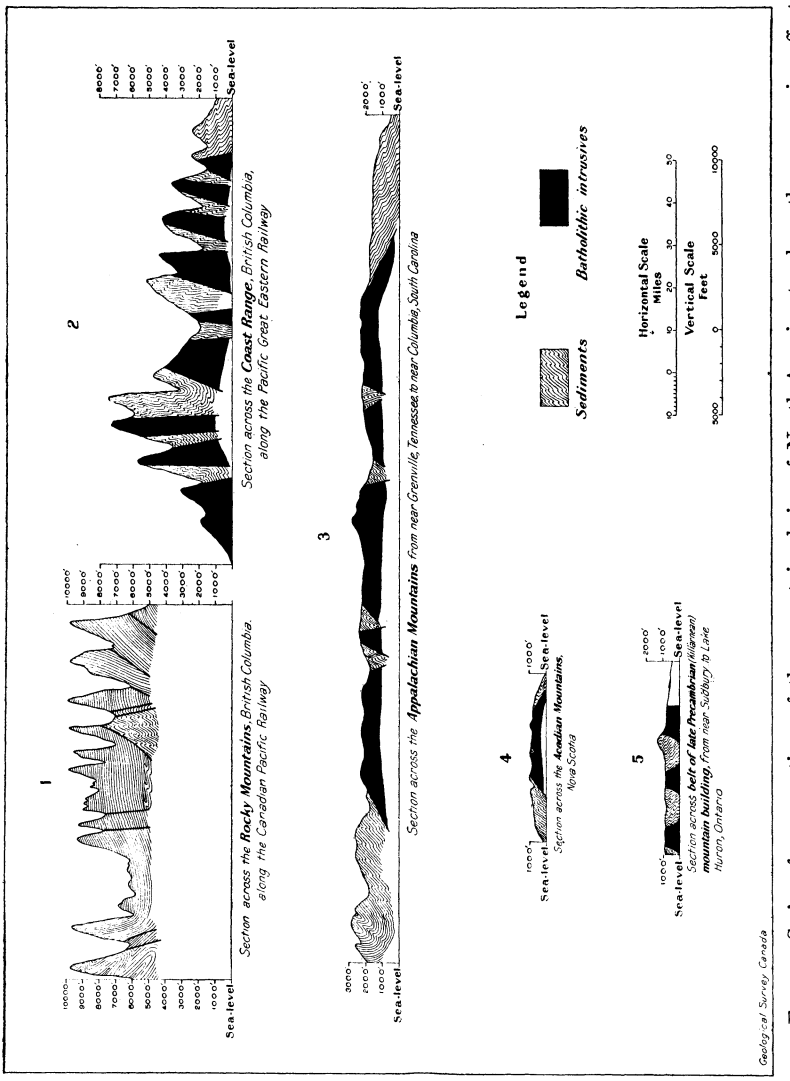

FIG. 2.—Series of cross sections of the mountain chains of North America to show the progressive effect of erosion in laying bare batholithic intrusions, and to show also the genetic relationship between mountain-building and the geology of the Precambrian field.

features that can scarcely be included as part of the Precambrian Shield peneplain. They rise in a solid, broad-based range 60 miles long and as much as 800 feet above the surrounding country.

Their mountainous aspect is enhanced by the fact that they consist of white, Lorrain quartzite and, when seen from any considerable distance, look as if they were covered with snow. The last of the five cross-sections in Figure 2 is through Lacloche Mountains. The sediments forming these mountains are Precambrian (Huronian), and the intrusive granitic batholiths are late Precambrian (Killarney).

Figure 2 has been introduced for the purpose of demonstrating that the associated phenomena of regionally deformed strata and batholithic intrusion are results and criteria of mountain-building and that by sufficiently protracted erosion a mountain system may be reduced to a peneplain having the topographic appearance and geological characteristics of northern Ontario. Endeavor will now be made to apply these criteria to the Precambrian Shield and to outline the chief events in the physiographic history of the northeastern part of Ontario, proceeding from the present as far back in time as the geological record has been interpreted.

Figure 3 shows the distribution of the essential geological elements in northeastern Ontario with which this thesis is immediately concerned. It also contains a tabular record of the geological periods. Periods not represented by rock formations in the region are shown in brackets. The larger spaces represent gaps in the record of intervals of erosion, and an attempt has been made to indicate, conservatively, by the size of the space, the length of time unrepresented by rock formations.

Let us take that part of the record from the Ordovician period to the present. Only a few of the series of formations are present—the Ordovician, Silurian, part of the Devonian, a little of what Mr. Keele regards as Cretaceous,[1] and the Pleistocene. All these formations lie horizontally or dip at very low angles. The Ordovician, Silurian, and Devonian are limestones, shales, and sandstones that contain fossil remains of marine animals. The Cretaceous contains beds of lignite and was presumably laid down on land or very near land. The Pleistocene consists of glacial bowlder clay and stratified clays and sands laid down in postglacial lakes. The careful studies of glacialists, Coleman, Johnston, Taylor, and others, have

[1] *Summary Report, Geol. Surv., Can.* (1919), Part G.

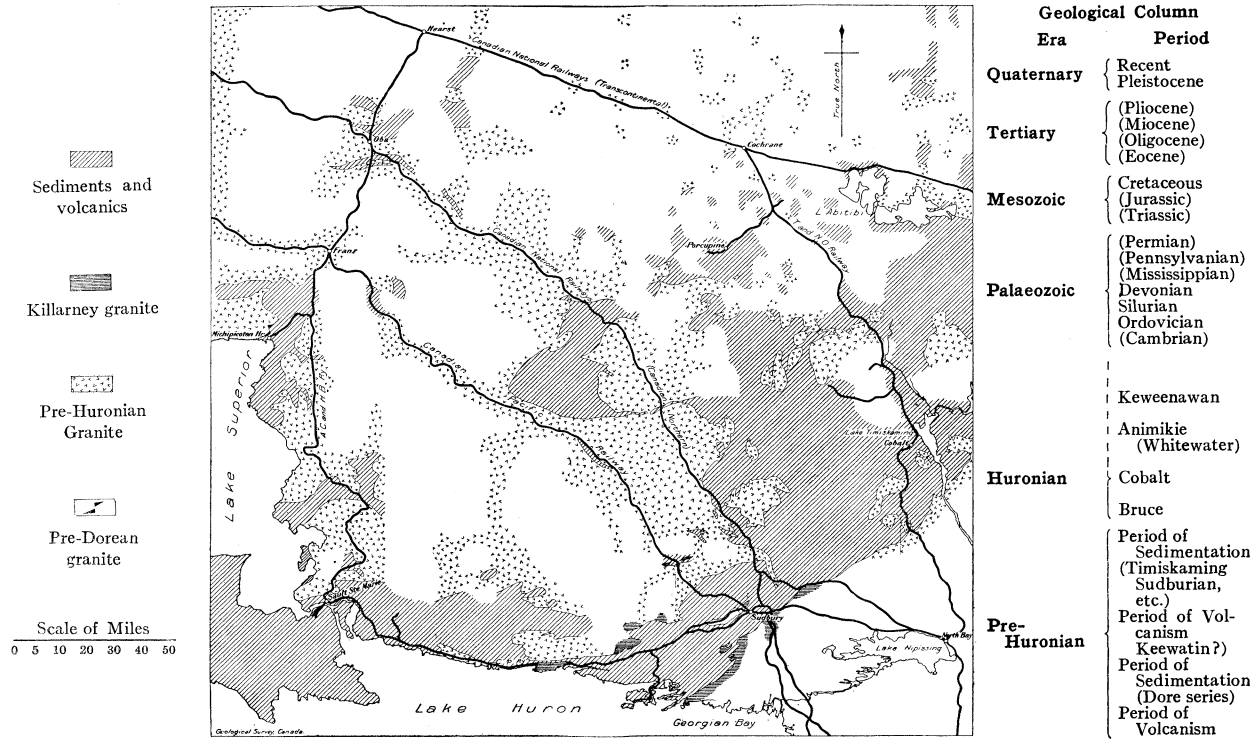

FIG. 3.—Map of Northeastern Ontario to show the known distribution of the batholithic intrusives (Painters) which are of three distinct ages and are related to three corresponding processes of mountain-building.

shown that the northeastern part of the continent, released from its load of ice, has readjusted itself, since the Glacial period, by gentle rising and tilting movements. There are no violently disturbed formations among these. There can be no doubt, then, that from Ordovician time until now northeastern Ontario has experienced only gentle oscillations in level and shallow marine submergence.

Let us take next the section of time from the beginning of the Bruce period until the end of the Keweenawan. This time is represented by a blanket of sediments aggregating over 30,000 feet in thickness, in the southern part of the region of northeastern Ontario, but thinned out to nothing by erosion, toward the north. The Bruce series is in part a land formation, and was for the remaining part apparently laid down at the edge of a continent; the Cobalt and Keweenawan series are both continental. In the northern part, these formations (represented by the Cobalt series) lie almost flat, or in open folds. Consequently it can be said with assurance that from the time of their deposition this northern part of the region has experienced no movements but those of rise and fall and mild compressional folding. Tracing these sediments southward, however, they become progressively more closely folded. South of a line drawn eastward and westward through Wanapitei Lake, the folds are tight and have a definite eastwest, axial course. Small masses of granite, intrusive in all these formations, appear at Cartier, at Sudbury, and at other points and, finally, in a line running northeasterly from Killarney, the Bruce series and later Precambrian sediments are abruptly truncated by a granite batholith of undetermined extent. How far southward this condition extends cannot be ascertained, because, from Lake Huron southward, the Precambrian formations are covered by the horizontal Palaeozoics.

It is abundantly clear that—if the associated phenomena of close regional folding and batholithic invasion indicate mountain-building—in late Precambrian time the southern part of the region shown on this map was compressed to form a system of mountains. These mountains occupied only the southern part of northeastern Ontario. They extended west along the south side of Lake Superior

at least as far as Duluth. How far eastward they extended is not known, nor, owing to the cover of Palaeozoic sediments, how far south.

Between Keweenawan and Ordovician time these late Precambrian (Killarnean) mountains were worn down to a condition probably not greatly different from that of the Adirondacks today, and certainly greater relief than the Lacloche Mountains of today, for these latter have since endured additional erosion from Palaeozoic time onward. A few peaks of the Killarnean Mountains now project through the Palaeozoics on Manitoulin Island; and bore-holes that have been made near by in the search for oil indicate a submountainous local relief of more than 800 feet in the floor upon which the Ordovician formations were laid.

Let us next consider the period of time that elapsed from the commencement of deposition of the Doré sedimentary series until the Timiskaming series and Sudbury series were completed. The Doré series is almost certainly of continental origin. It is thought to have been deposited under conditions like those which governed the deposition of the silts and gravels in the interior plateau of British Columbia. The Keewatin volcanics are believed by some geologists to be of submarine origin, owing to the abundance among them of ellipsoical greenstone; but the writer can find no evidence to support this view. It appears, rather, that they were deposited on land and in small bodies of water. Recent studies of the Timiskaming series by Mr. H. C. Cooke[1] indicate a continental origin for this series also. Judging by the extremely variable thickness of the sediments throughout this group, their coarse texture, and apparently local deposition, the region may have been one of considerable topographic relief during the entire time.

Except in the southern portion of northeastern Ontario, these formations are extraordinarily folded, schistified and faulted, and invaded by granite batholiths of huge size. In fact, they are represented now only by irregular patches which were down-folded low enough to escape erosion. If intense regional disturbance and batholithic invasion indicate mountain-building, it must be con-

[1] "Kenogami Lake and Larder Lake Areas," *Geol. Surv., Can.*, Memoir in course of publication.

cluded that following Timiskaming time the whole region, shown in Figure 3, was mountain-built. The southern portion was long afterward involved in the Killarnean mountain-building and, in that part, any evidence of this earlier orogeny was pretty completely demolished; but there is little doubt that the older mountains extended over the whole region.

Between the finish of Timiskaming sedimentation and the commencement of the Bruce period these older, pre-Huronian mountains must have been uplifted, carved, and completely destroyed, for the Bruce series lies upon a peneplained surface evidently quite as maturely eroded as the surface of today. The evidence for this has been discussed at length in various Geological Survey reports,[1] and need not be repeated. Attention need be directed here only to the length of time required for this complete physiographic cycle; the Appalachian Mountains, which are not yet nearly so completely leveled, have existed since Permian time.

Just as the Killarnean mountain-building demolished in the southern part of the region the evidence of earlier geological history, so it might be expected the pre-Huronian mountain-building, which extended over the whole region, would have obliterated all of the geological record anterior to the deposition of the Doré series. This is not wholly the case. When the Timiskaming series was first described by W. G. Miller,[2] he noted that it contained granite pebbles. Many years before, Logan noted the presence of granite bowlders in the Doré series, though, at that early stage in Canadian geological work, he could not be sure of the position of this series in the geological scale. These granite inclusions in the oldest known sediments have afforded ground for much speculation regarding the nature of the surface from which they were derived, and upon which they were deposited.

It was not until 1920 that the ancient granite which supplied these pebbles was identified *in situ* beneath the Doré series, near Michipicoten Harbor. At that place the Doré series lies tilted at an angle of 50° or more against a basement of older rocks, from

[1] M. E. Wilson, *Geol. Surv., Can.*, Memoir No. 39; W. H. Collins, *op. cit.*, Memoir Nos. 33, 95, and another not yet published.

[2] *Ann. Rep. Ontario Bureau of Mines*, Vol. XIX, Part 2, p. 62.

which it derived most, if not all, its pebbles and bowlders. This basement is in part composed of schistose volcanics and in part of gray granite. Its extent, away from the Doré series, has not been worked out and will be very difficult to determine; but there is quite enough to indicate that a third granite, older than the Killarney and the pre-Huronian granites, exists, and had been laid bare in large volume in pre-Doréan time.[1] Was this pre-Doréan granite indicative, like its successors, of a third mountain-building activity that took place in a time too remote for the mind to comprehend?

Regarding the physiographic conditions governing the deposition of the Doré series the authors of the report mentioned speculate as follows:[2]

> The writers are inclined to visualize Michipicoten district at the commencement of Doréan time as a region of rugged relief and waning volcanic activity. During early Doréan time this land surface, devoid of vegetation, was eroded rapidly, some of the deep-seated granite masses being uncovered to provide the great quantities of granite pebbles and bowlders found in the Doré conglomerate. The rude granite and porphyry conglomerate and associated formations in the lower part of the series were formed nearly in place by rock disintegration, with a consequent aggradation, or wearing down of summits and filling in of depressions in the surface of the country.

SUMMARY OF PHYSIOGRAPHIC HISTORY

1. The Doré series, the earliest known Precambrian sediment in northeastern Ontario, was deposited as a continental formation upon a surface of rugged topography. An earlier period of mountain-building and erosion is suggested by the presence, subjacent to the Doré conglomerate, of an older granite mass, apparently of large dimensions.

2. From Doréan time until the end of Timiskaming time the region was apparently a land area of considerable, if not high relief, and the seat of prolonged volcanic activity.

3. A period of mountain-building (pre-Huronian) and complete reduction to a peneplain followed, affecting the whole region. A

[1] W. H. Collins and T. T. Quirke, *Geol. Surv., Can.*, Memoir in course of preparation.

[2] *Loc. cit.*

conception of the time involved is obtainable by comparison with the rate of formation and reduction of the Rocky, Coast, and Appalachian Mountains.

4. From the Bruce period until the Keweenawan the region was apparently a land area or one of shallow and intermittent submergence.

5. Following or during the Keweenawan another (third) process of mountain-building (Killarnean) took place which affected only the southern portion of the region. These Killarnean Mountains were reduced to a state of fairly low relief before the Ordovician marine sediments were deposited upon them.

6. From Ordovician time until the present the region has been subjected only to gentle epeirogenic oscillations and shallow submergence; its relief was low throughout this interval and it now forms a glaciated peneplain.

7. From the earliest time of which a geological record remains, the region of which northeastern Ontario is part, has behaved as a positive element of the earth's crust.